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Cobb angle measurement and pelvic inclination in children with spastic cerebral palsy: A cross-sectional study

Cobb angle measurement and pelvic inclination in spastic cerebral palsy children

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Abstract
Aim: This study aimed to determine the correlation between pelvic inclinations and spinal alignment in children with cerebral palsy.
Material and Methods: Sixty children with spastic cerebral palsy from both sexes, aged 5 to 10 years, only with grade 1 or 1+ on the Ashworth scale, who can stand independently without assistive devices level I, II according to the Gross Motor Function Classification System (GMFCS)were selected. All children were assessed for measuring pelvic inclination using pelvic inclinometer and spinal alignment using radiological X-rays, and then measuringthe Cobb angle and correlation between the results.
Results: There was a significant moderate positive correlation between the right anterior pelvic tilt and theLordotic Cobb's angle ($r = 0.314$, $p = 0.01$) and a significant weak positive correlation between left anterior pelvic tilt and Lordotic Cobb angle ($r = 0.268$, $p = 0.03$). However; there was a moderate negative significant correlation between the right anterior pelvic tilt and kyphotic Cobb's angle ($r = -0.313$, $p = 0.01$) and a significant weak negative correlation between left anterior pelvic tilt and kyphotic Cobb angle ($r = -0.27$, $p = 0.03$).
Discussion: The extent of the lumbar Lordotic curve and the degree of pelvic inclination in a standing position are associated with the muscle lengths of the sagittal-plane pelvic rotators and the performance (strength) of the abdominal muscleswhich are affected in a patient with cerebral palsy (as they have weakness in core muscles). The rehabilitation program for children with cerebral palsy should include pelvic tilt correction and core stability exercise.

Keywords
Pelvic inclination; Spinal alignment; Pelvic inclinometer; Spastic cerebral palsy

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Introduction

Cerebral Palsy (CP) is described as a group of disorders of the development of movement and posture, causing activity limitation due to non-progressive disturbances that occurred in the developing fetal or infant brain [1]. Spasticity is the most common motor disorder seen in CP defined as an abnormally increased resistance to externally imposed movement about a joint. Spasticity causes hypertonia that increases with increasing velocity of movement or causes a spastic catch. It can affect the entire body, including the trunk, face, and neck. It tends to be worse in the lower limbs in those with bilateral involvement, and in the upper limbs in those with unilateral involvement [2]. Alignment to anatomical landmarks of the pelvis, most commonly the anterior superior iliac spines and the pelvic symphysis defines the anterior pelvic plane. The orientation of the anterior pelvic plane can differ considerably in the standing or lying position with respect to the frontal plane. This difference is defined as pelvic inclination. Zero pelvic inclination occurs when the anterior pelvic plane is parallel to the frontal plane [3]. An inclinometer is a methodwhich was introduced for measurement of pelvic tilt of the anterior plane. These authors constructed an inclinometer that could be pressed firmly against the anterior pelvic spines and the symphysis [3]. Children with CP have an increased risk of developing scoliosis compared to other patient populations. Muscle weakness, truncal imbalance, and asymmetric tone in paraspinal muscles have long been implicated in the onset of scoliosis in CP, but there is little literature to support this theory [4]. The prevalence of spinal deformities in patients with cerebral palsy ranges from 10% of ambulatory patients with spastic hemiplegia to 65% of those with spastic quadriplegia [5]. Neuromuscular scoliosis that occurs in CP is typically a C-shaped curve that is often kyphoscoliotic and associated with pelvic obliquity [4].

In the standing position, with the pelvis held in an anteriorly tilted position, the spinal column rests on the sacrum. The superior surface of the sacrum slopes forward. This is described as the “base angle” of the lumbar spine - the angle between the plane through the L5-S1 interspace and the horizontal. The greater the base angle, the more pronounced the lumbar lordosis [6].

Right anterior pelvic tilt is measured by using the pelvic inclinometer from the anterior superior iliac spine (ASIS) to the posterior superior iliac spine on (PSIS) on the right side, and also the left anterior pelvic tilt is measured from the ASIS to the PSIS on the left side.

Material and Methods

This study was carried out on 60 childrenof both sexes with spastic cerebral palsy, aged 5 to 10 years, who were selected from the Outpatient clinic of Cairo university hospitals, Egypt (30 children with spastic hemiplegia, 30 children with spastic Diplegia). They were enrolled and assessed for their eligibility to participate in the study, as they were selected only with grade 1 or 1+ on the modified Ashworth scale and can stand independently without assistive devices level I, II in Gross Motor Function Classification System (GMFCS). The children were excluded if they had moderate or severe mental ability or if they had taken a Botox injection in the last 6 months or underwent orthopedic surgeries in the last 2 years. All children were assessed for pelvic inclination using pelvic inclinometer and for spinal alignment using radiological X-rays.

Ethical consideration

This study was approved by Cairo University Research Ethical Committee and written informed consent was obtained from the parents to participate in this study.

Measurement of pelvic tilting:

In a standing position, the child was asked to take the most erect position as much as possible, and stand barefoot, and with the hand-held pelvic inclinometer, pelvic inclinationcould be measuredby determining the angle formed by a horizontal line drawn between the anterior superior iliac spine (ASIS) and the posterior superior iliac spine (PSIS). Each measurement was repeated two or three times so that the reliability of the measurements could be determined [7].

Measurement of Cobb’s angle:

For the lateral view, the child was asked to take the most erect position as much as possible, looking straight ahead with shoulders flexed and hands placedforward. This keeps the upper extremities from being superimposed over the spine on the lateral view. The most commonly used and most accurate measurement of spinal curvature is the Cobb angle. It is obtained by measuring the maximal angle from the superior endplate of the superior-end vertebra to the inferior endplate of the inferior- end vertebra. If endplates are difficult to visualize, the borders of the pedicles may be used. The measurements obtained using this method should be precise and reproducible [8].

Statistical analysis:

Descriptive statistics were utilized in presenting the subjects demographic and clinical data. Quantitative variables were summarized using mean and standard deviation while categorical variables were summarized using frequencies and percentage. Pearson Correlation Coefficient was conducted to determine the correlation between pelvic tilt, lordotic Cobb angle and kyphotic Cobb angle. The level of significance for all statistical tests was set at $p < 0.05$. All statistical measures were performed through the statistical package for social sciences (SPSS) version 25 for Windows.

Results

Subjects characteristics:

Sixty children with CP participated in this study. Participant characteristics are presented in Table 1. Twenty (33.3%) subjects had right-sided hemiplegia, 10 (16.7%) had left-side hemiplegia and 30 (50%) had Diplegia. Spasticity ranged from grade I to grade I+ and 47 (78.3%) subjects had grade I GMFCS and 13 (21.7%) had grade II.

Lordotic Cobb angle, kyphotic Cobb angle, right and left anterior pelvic tilt angles in the study group

The mean ± SD Lordotic cobb angle in the study group was 36.03 ± 14.67 degrees and kyphotic Cobb angle was 42.68 ± 13.77 degrees. The mean ± SD anterior pelvic tilt angle on the right side was 12.25 ± 5.39 degrees and that on the left side was 13.2 ± 5.41 degrees.

Correlation between pelvic tilt, Lordotic Cobb's angle and kyphotic Cobb's angle in the study group

There was a significant moderate positive correlation between right anterior pelvic tilt andLordotic Cobb angle (r = 0.314, p = 0.01) and a significant weak positive correlation between left anterior pelvic tilt and Lordotic Cobb angle (r = 0.268, p = 0.03). However, there was a moderate negative significant correlation between right anterior pelvic tilt and kyphotic Cobb's angle (r = -0.313, p = 0.01) and a significant weak negative correlation between left anterior pelvic tilt and kyphotic Cobb angle (r = -0.27, p = 0.03) (Table 3, Figures 1-4).

Table 1. Participant characteristics

	Study group
Age, mean ± (SD), (years)	6.78 ± 1.76
Weight, mean ± (SD), (kg)	39.8 ± 14.64
Height, mean ± (SD), (cm)	128.13 ± 7.66
Sex, N (%)	
Females	30 (50%)
Males	30 (50%)
Diagnosis, N (%)	
Rt Hemiplegia	20 (33.3%)
Lt Hemiplegia	10 (16.7%)
Diplegia	30 (50%)
GMFCS, N (%)	
Grade I	47 (78.3%)
Grade II	13 (21.7%)
Modified Ashworth scale, N (%)	
Grade I	47 (78.3%)
Grade I+	13 (21.7%)

SD: Standard deviation; GMFCS: Gross motor function classification system

Table 2. Mean Lordotic Cobb angle, kyphotic Cobb angle, Right and left anterior pelvic tilt anglesin the study group

	Study group		
	Mean ± SD	Minimum	Maximum
Lordotic cobb angle (degrees)	36.03 ± 14.67	7	68
Kyphotic cobb angle (degrees)	42.68 ± 13.77	16	77
Rt anterior pelvic tilt angle (degrees)	12.25 ± 5.39	3	25
Lt anterior pelvic tilt angle (degrees)	13.2 ± 5.41	3	25

SD: Standard deviation

Table 3. Correlation between pelvic tilt, Lordotic Cobb angle and kyphotic Cobb angle in the study group

	Rt anterior pelvic tilt angle (degrees)		Lt anterior pelvic tilt angle (degrees)	
	r	p	r	p
Lordotic Cobb angle (degrees)	0.314	0.01	0.268	0.03
Kyphotic Cobb angle (degrees)	-0.313	0.01	-0.27	0.03

r- value, Pearson correlation coefficient value; p- value, probability value

Discussion

The pelvis in the sagittal plane is commonly analyzed using 3 angular measurements: pelvic tilt, pelvic incidence, and sacral slope [9].

Pelvic tilt is defined by the line through midpointof the sacral plate and midpoint of the femoral heads axis, and the vertical "pelvic incidence", which was defined as the angle between the line perpendicular to the sacral plate at its midpoint, and the line connecting this point with the axis of the femoral heads [10]. Sacral slope is defined as the angle between the horizontal and the sacral plate. It is hypothesized that the increased sacral slope creates greater lumbosacral lordosis [11].

It is a fact that the spine rests on top of the pelvis. It is unavoidable, therefore, that anything that affects the posture or stability of the pelvis of an upright human will also affect the spine. This applies to many postures and movements, although the standing and sitting postures are of most interest to ergonomists [12].

According to scientific studies, in a standing position with the pelvis held in an anteriorly tilted position, the spinal column rests on the sacrum. The superior surface of the sacrum slopes forward. This is described as the "base angle" of the lumbar spine - the angle between the plane through the L5-S1 interspace and the horizontal. The greater the base angle, the more pronounced the lumbar lordosis [6].There is never a lumbar curve if the base angle was less than 18 degrees. Conversely, a rounded back has never been seen if the base angle was greater than 10 degrees [12].The idea of this study corresponds to the study by Kendall et al who said that the extent of the lumbar Lordotic curve and the degree of pelvic inclination in the standing position are associated with the muscle lengths of the sagittal-plane pelvic rotators and the performance (strength) of the abdominal muscles. Such assumed relationships are based on the anatomy of the muscles and their potential for action on the pelvis. The abdominal muscles tilt the pelvis posteriorly, and the lumbar erector spinae muscles tilt it anteriorly [13]. Thus, the lengths of the lumbar erector spinae and abdominal muscles, according to another theory, should also influence the size of the lumbar Lordotic curve and the degree of pelvic inclination in the standing position. For example, if the lumbar erector spinae muscles are shortened and the abdominal muscles are relatively lengthened, the degree of pelvic inclination and size of the lumbar lordosis would be expected to be greater than normal. Therefore, in a normal standing position, the degree of pelvic inclination is related to the lumbar curve, and both are related to the performance and length of the back and abdominal muscles [14]. During posterior pelvic tilting, both the lower fibers of the rectus abdominis and the gluteals work, and reduce lumbar lordosis due to posterior pelvic tilting. The anterior pelvic tilt is actually a quite normal postural position. However, excessive anterior pelvic tilting beyond the "normal" range is a result of weakness in the abdominal muscles and tightness in the iliopsoas [15]. Adopting a maximal anterior pelvic tilt increased lumbar lordosis by an average of10.8° and adopting a maximal posterior pelvic tilt decreased lumbar lordosis by an average of 9° in the standing position. Differences from Hyun Park's study may be due to individual variables and the postures. The results of Levine'sstudy support the idea that pelvic tilting affects lumbar lordosis [16].

Muscle weakness is reported to be a common symptom in children with cerebral palsy [17], and spinal deformity is highly prevalent in patients with neuromusculardisorders[18]. Furthermore, many of these children develop substantial pelvic obliquity, which leads to positionaldiscomfort, sitting intolerance, and complications such aspressure sores.Children with CP have poor trunk stability (weak core muscles) due to the low muscle tone of the trunk and proximal muscles and muscle weakness [6]. Since in children with cerebral palsy, the abdominal and back muscles are more affected due to the weakness of the abdominal muscle and tightness of the erector spinae and iliopsoas muscles, which affect the pelvic tilting and lumbar lordosis (increase pelvic tilting anteriorly, that increaseslordotic curve).

According tothe study byJean-Luc Cle´mentet al (2013), the proximal part of lordosis depends on the thoracic kyphosis, and the distal part depends on the pelvic incidence [19]. Since the cervical, thoracic, and lumbar spinal regions are biomechanically related, any change in each arch might be due to the postural alteration in other arches [15]. According to some studies,with an increase in lordosis, thoracic kyphosis also increases; however, some studies (supporting our results) have indicated that an increase in lordosis is accompanied by a decrease in kyphosis [20, 21].

There was a significant moderate positive correlation between right anterior pelvic tilt and Lordotic Cobb angle (r = 0.314, p = 0.01) and a significant weak positive correlation between left anterior pelvic tilt and Lordotic Cobb angle (r = 0.268, p = 0.03). However, there was a moderate negative significant correlation between right anterior pelvic tilt and kyphotic Cobb's angle (r = -0.313, p = 0.01) and a significant weak negative correlation between left anterior pelvic tilt and kyphotic Cobb angle (r = -0.27, p = 0.03) (Table 3). Due to significant pelvic asymmetry, due to variations in pelvic morphology this is achieved by the ischial spine-pubic symphysis angle and the side-to-side difference in pelvic height. This latter finding is in agreement with Badii et al, who used radiographic techniques and defined a measure of innominate asymmetry. This makes anterior innominate rotation (asymmetrical anterior pelvic tilt) rotation between two sides of pelvis [22].

Regarding the relationship between thoracic kyphosis and lumbar lordosis, other studies [23] have shown a weak correlation between thoracic kyphosis and lumbar lordosis with. However, Yong [24] described a strong correlation between thoracic kyphosis and lumbar lordosis. In addition, Legaye J and Duval-Beaupere G (2005) have found a strong correlation between pelvic tilt angle and thoracic kyphosis and lumbar lordosis, assessing the onset of spinal deviation with pelvic evaluation (consistent with the results of our study) [25]. In conclusion, the normal anatomy of the lumbar curve is lordosis due to theanatomical position of the lumbar spine rested on the sacrum by a certain angle, and also the normal anatomy of the pelvis is anterior pelvic tilting. Since the lumbar curve is biomechanically related to the pelvic region, any movement of the pelvis affects lumbar curve. The extent of the lumbar lordotic curve and the degree of pelvic inclination in the standing position are associated with the muscle lengths of the sagittal-plane pelvic rotators and the performance (strength) of the abdominal muscles.The abdominal muscles tilt the pelvis posteriorly, whereas the lumbar erector spinae muscles tilt it anteriorly. When the erector spinae muscle is shortened and the abdominal muscle is weakened, this increasesthe anterior pelvic tilting and also lumbar lordosis. Since in children with cerebral palsy abdominal and back muscles (core muscles) are more affected, this affects the pelvic tilting and lumbar lordosis (increases pelvic tilting anteriorly, which increasesthe lordotic curve). Since cervical, thoracic, and lumbar spinal regions are biomechanically related, any change in each arch can be associated with the postural alteration in other arches. Thus, an increase in lumbar lordosis may also affect the thoracic curve and increase thoracic kyphosis.

Conclusion:

This study is important for children with cerebral palsy, when the core muscles are affected, ananterior pelvic tilt occurs which is most common, as this increases lumbar lordosis and may increase the thoracic curve (thoracic kyphosis).Therefore, correction of pelvic inclination by strengthening muscles around the pelvis, mainly pelvic extensors, and core stability exercises may decrease anterior pelvic tilt and decrease lumber lordosis. Thus these exercises should be integrated into the rehabilitation program for children with cerebral palsy, since there is a medium correlation between the pelvic inclination and lumbar lordosis.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

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References

1. Liao H, Liu Y, Liu W, Lin Y. Effectiveness of Loaded Sit-to-Stand Resistance Exercise for Children with Mild Spastic Diplegia: A Randomized Clinical Trial. Arch Phys Med Rehabil. 2007; 88 (1): 25-31.

2. Sakrewski L, Ziyiani J, Boyd R. Systematic review and meta-analysis of therapeutic management of upper limb dysfunction in children with congenital hemiplegia. Pediatrics. 2009; 123 (6):e1111–22.

3. Lembeck B, Mueller O, Reize P, Wuelker N. Pelvic tilt makes acetabular cup navigation inaccurate. Acta Orthop. 2005; 76(4):517-23.

4. McCarthy J, D'Andrea L, Betz R, Clements DH. Scoliosis in the child with cerebral palsy. J Am AcadOrthopSurg. 2006; 14(6):367–75.

5.Brayda-Bruno MCinnella P, Vincitorio F, Lovi A, Grava G, Brayda-Bruno M. Spinal Fusion With Cotrel-Dubousset Instrumentation for Neuropathic Scoliosis in Patients With Cerebral Palsy. Spine. 2006; 31(14):E441-7.

6. Mandal AC. The correct height of school furniture. Human Factors.1982; 24: 257-69. 7. Mayston MJ. People with cerebral palsy: effects of and perspectives for therapy. Neural Plast. 2001; 8(1-2):51-69.

8. Cobb JR. Outline for the study of scoliosis. Am Acad Orthop Surg Instr Course Lect. 1948;5:61–75.

9. Labelle H, Roussouly P, Berthonnaud E, Dimnet J, O'BrienM. The importance of spino-pelvic balance in L5-s1 developmentalspondylolisthesis: a review of pertinent radiologicmeasurements. Spine (Phila Pa 1976). 2005; 30 (Suppl.6):S27–34.

10. Boulay C, Tardieu C, Hecquet J, Be´naim C, Mitulescu A, Marty C, et al. Anatomical reliability of two fundamental radiological andclinical pelvic parameters: incidence and thickness. Eur J Orthop Surg Traumatol. 2005;

15(3):197-204.
11. Lim JK, Kim SM: Difference of sagittal spinopelvic alignments between degenerative spondylolisthesis and isthmic spondylolisthesis. J Korean Neurosurg Soc. 2013; 53:96–101.
12. Schoberth H. Seating: Posture, injuries and furniture. Berlin: Springer Verlag; 1962.
13. Kendall FP, McCreary EK, Provance PG, Rodgers M, Romani WA. Muscles, testing and function: with posture and pain. Baltimore, MD: Williams & Wilkins; 1993.
14. Youdas JW, Garrett TR, Harmsen S, Suman VJ, Carey JR. Lumbar lordosis and pelvic inclination of asymptomatic adults. Phys Ther. 1996 76(10):1066-81.
15. Lau KT, Cheung KY, Chan KB, Chan MH, Lo KY, Chiu TT. Relationships between sagittal postures of thoracic and cervical spine, presence of neck pain, neck pain severity and disability. Man Ther. 2010;15(5):457-62.
16. Levine D, Whittle MW. The effects of pelvic movement on lumbar lordosis in the standing position. J Orthop Sports PhysTher. 1996; 24(3):130-5.
17. Toner LV, Cook K, Elder GC. Improved ankle function in children with cerebral palsy after computer-assisted motor learning. Dev Med Child Neurol. 1998; 40(12): 82935.
18. Pehrsson K, Larsson S, Oden A, Nachemson A. Long-term follow-up of patients with untreated scoliosis. A study of mortality, causes of death, and symptoms. Spine (Phila Pa 1976). 1992;17(9):1091-6.
19. Cle´ment J-L, Geoffray A, Yagoubi F, Chau E, SollaF, Oborocianu I, et al. Relationship between thoracic hypokyphosis, lumbar lordosis and sagittal pelvic parameters in adolescent idiopathic scoliosis. 2013; 22(11): 2414–20.
20. Roussouly P, Nnadi C. Sagittal plane deformity: an overview of interpretation and management. Eur Spine J. 2010;19(11):1824-36.
21. Schwab F, Patel A, Ungar B, Farcy JP, Lafage V. Adult spinal deformity-postoperative standing imbalance: how much can you tolerate? An overview of key parameters in assessing alignment and planning corrective surgery. Spine (Phila Pa 1976). 2010; 35(25):2224-31.
22. Badii M, Shin S, Torreggiani WC, Jankovic B, Gustafson P, Munk PL, et al. Pelvicbone asymmetry in 323 study participantsreceiving abdominal CT scans. Spine. 2003; 28(12):1335–9.
23. Upasani VV, Tis J, Bastrom T, Pawelek J, Marks M, Lonner B, et al . Analysis of sagittal alignment in thoracic and thoracolumbar curves in adolescent Eur Spine J (2013) 22:2414–2420 2419 123 idiopathic scoliosis. How do these two curve types differ? Spine. 2007; 32(12):13559.
24. Yong Q, Zhen L, Zezhang Z, Bangping Q, Feng Z, Tao W, et al Comparison of sagittal spinopelvic alignment in Chinese adolescents with and without idiopathic thoracic scoliosis. Spine. 2012 37(12):E714-20.
25. Legaye J, Duval-Beaupere G. Sagittal plane alignment of the spine and gravity: a radiological and clinical evaluation. Acta Orthop Belg. 2005; 71(2):213–20.

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